minerals

Editorial

Editorial for Special Issue "Novel Methods and Applications for Mineral Exploration"

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1. Introduction

The mineral exploration industry is undergoing a profound transformation, reflecting not only the presence of some novel societal, economic, and environmental considerations, but also reflecting the changes in the deposits themselves, which tend to be deeper, with lower grades, and in more remote regions. On the other hand, recent technological advances, not only in geophysics and geochemistry, but in fields such as in artificial intelligence, computational methods, and hyperspectral exploration, to name but a few, have profoundly changed the way exploration is now conducted. This special volume is a representation of these cutting-edge and pioneering ways to consider and conduct exploration and should serve both as a valuable compendium of the most innovative exploration methodologies available and as a fore-shadowing of what form the future of exploration will likely take. As such, this volume is of significant importance and would be useful to any exploration geologist and company.

2. Review of the Papers in the Special Issue

The papers published in this Special Issue are diverse, with contributions in the fields of geophysics (four papers), computational methods (three papers), geochemistry (two papers), and one review paper on a specific deposit type. These distinctions are, of course, somewhat artificial, as modern exploration geophysics and geochemistry heavily rely on computation, data treatment, and interpretation. The individual contributions will be briefly reviewed here.

2.1. Geophysics

The contribution by Zhang et al. [1] provides an example of successful deep-seated deposit exploration, where the geological background was interpreted in combination with geophysical methods such as gravity, aeromagnetic, and controlled source audio-frequency magnetotellurics (CSAMT). The method was applied to one of the largest Ni–Cu–(PGE) deposits in the world: The Jinchuan Cu–Ni sulfide deposit in the North China Craton. The authors found that medium-low resistivity, high density, and high magnetic anomaly areas near the structural belt tend to correspond to the known ore-bearing rocks in the area, thus providing an exploration tool for this type of deposits.

The paper by Guo et al. [2] reports the application of electromagnetics (EM) combined with controlled source audio-frequency magnetotellurics (CSAMT) to the exploration of the Eagle's Nest lead–zinc deposits in Jianshui, SW China. Importantly, the authors report several specific optimizations of the methods, based on previously obtained dual- frequency induced polarization data, allowing them to infer that the Pb–Zn ore-bodies correlate with high induced polarization and low resistivity, suggesting that EM and CSAMT can be used for similar deposits in the area.

The contribution by Zhang et al. [3] reports the development of a geophysical exploration method based on the joint inversion of 2D gravity, gradiometry, and magnetotelluric data, based on data-space and normalized cross-gradient constraints. Both a synthetic example and a real-world example (from the Haigou gold mine, Jilin, Northern China) are provided to test the method, allowing the authors to conclude that the method can be applied with relative ease and can be useful, in particular in geologically complicated terrains.

The next paper, by Zhang et al. [4], also deals with the joint 2D inversion of gravity and magnetotelluric data that are structurally constrained in this study. A synthetic and a real-world (Linjiang Cu mine, Jilin, Northern China) example are used to test the method, allowing the authors to conclude that the elastic-net regularization method and the cross-gradient constraints help to provide a more meaningful, integrated interpretation of the subsurface. The method results in more detailed and sharp boundary models leading to the less ambiguous distinction of geologic units and materials.

2.2. Geochemistry

The contribution by Steiner et al. [5] provides an elegant example of a combined stream sediment geochemistry and automated mineralogy approach to the exploration of the Kagenfels and Natzwiller fractionated granites, Vosges Mountains, NE France. Characteristic geochemical fractionation and principal component analysis trends are combined with mineralogical evidence from a series of stream sediment samples to suggest that the fractionated granite suites in the northern Vosges Mountains contain rare metal mineralization indicators and are therefore highly prospective for further exploration.

An intriguing paper by Harmon et al. [6] describes a novel analytical tool that has high potential in mineral exploration: laser-induced breakdown spectroscopy (LIBS). A review of previously published research and new data demonstrates the high usefulness of this method in geochemical fingerprinting, sample classification and discrimination, quantitative geochemical analysis, rock characterization by grain size analysis, and in situ geochemical imaging. Given that LIBS data can be obtained in the field by a hand-held instrument, LIBS has high potential in mineral exploration.

2.3. Computational Methods

The contribution by Mao et al. [7] reports the results of mineral prospectivity modeling, involving a combination of 3D geological modeling, 3D spatial analysis, and prospectivity modeling, applied to the Axi low-sulfidation epithermal gold deposit NW China. The results suggest that genetic algorithm optimized support vector regression (GA-SVR) outperforms multiple nonlinear regression or fuzzy weights-of-evidence in complicated nonlinear and high-dimensional cases of prospectivity modeling.

The contribution by Battalgazy et al. [8] focuses on the use of complex bi-variate plots and provides an algorithm for combining projection pursuit multivariate transform (PPMT) with a conventional (co)-simulation. The proposed algorithm is applied to geochemical exploration data from a real-world case: a deposit in south Kazakhstan.

A valuable contribution by Chen et al. [9] provides a novel method for the use of a one-class support vector machine (OCSVM) algorithm by combining it with the bat algorithm. This combination results in the automatic optimization of the initialization parameters of the OCSVM. The bat-optimized OCSVM is then applied to the mineral prospectivity of the Helong district, Jilin Province, China.

2.4. Review of a Deposit Type

The paper by Steiner [10] provides a comprehensive review of the main controls for the formation of Li–Cs–Ta pegmatite deposits. The review recommends an optimized grassroots exploration workflow and suggests the methods that can be used in this exploration. It also provides specific case studies from the Vosges Mountains in northeast France and the Kaustinen pegmatite field in west Finland. It is a compendium that is very valuable as a "cookbook" to guide exploration for Li–Cs–Ta pegmatite deposits.

3. Summary

Exploration geologists have always been very innovative and have always strived to develop and utilize the most advanced exploration techniques. This has never been as visible as today, when some very significant technological advances, specifically in computational power, artificial intelligence, and machine learning, have opened completely new perspectives and vistas allowing not only to extract much more and more detailed and specific information from the raw observational data, but also to develop completely new and exciting exploration methods and techniques. The present volume provides a snapshot of the fore-front of exploration research, underlining the significance of the collaboration between academia-based scientists and the exploration industry.

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